Ontario Department of Agriculture

FRUIT BRANCH

BULLETIN 271

THE APPLE MAGGOT

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Fig —Apple Maggot Adult (female), enlarged about four times.

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SUMMARY.

For over twenty years the Apple Maggot or Railroad Worm has been recognized as a pest of apples in Ontario. From time to time it has appeared in large numbers in infested orchards and has caused serious losses, in some instances amounting to the entire crop. Up to the present the insect has been found in most of the southern counties extending from the Ottawa River on the east to Lake Huron and the Detroit River on the west, and it is highly probable that it occurs in all counties where apples are grown. Fortunately, the total number of infested orchards is small, probably less than five per cent. in any county and much less than one per cent. in the province as a whole.

It is worthy of note that well-cared-for orchards which are properly sprayed are, as a rule, free or almost entirely free from this pest.

The adult insects commence to emerge from the soil in late June and early July, and continue to emerge for about seven weeks. They are blackish, two-winged flies, a little smaller than house-flies. The abdomen of the female is crossed by four white bands, and that of the male by three. The wings have conspicuous dark markings, arranged as shown in Fig. 3. Several days after emergence the female fly begins egg-laying. By means of a sharp sting-like ovipositor she inserts her eggs beneath the skin of the apple. The eggs hatch in five to six days and the larvæ or maggots derived from them tunnel their way here and there through the flesh of the apple, leaving behind them trails of dead brown tissue. The larvæ become mature when the fruit is ripe, by which time it has usually fallen. The larvæ then leave the apples, enter the soil and change to the pupal stage, in which stage the winter is passed. Most of the pupæ transform to flies the following summer. However, a certain percentage of them remain in the soil until the second summer and then emerge as flies at the usual time.

Injury is caused chiefly by the maggots tearing the apple pulp with their hook-like mouth parts and absorbing the juices. Pulp affected in this manner becomes brown and tough; hence the term "woody" which is frequently applied to maggot-infested apples. Badly infested fruit may become so honeycombed with larval tunnels that it will break down into a rotting mass.

The wounds made in the apple by the flies in ovipositing and the killing of tissues by maggots working near the skin, may give rise to malformations.

Serious loss may also be caused by the tendency of infested apples to drop prematurely.

The flies have extensible mouth-parts with rasp-like lobes, by means of which they feed on liquid or solid materials present on the leaves and fruit. This habit of feeding affords us a very satisfactory method of control by making it possible to poison the flies before they lay their eggs.

Control. Experiments conducted in Ontario during the past six years have definitely proved that the Apple Maggot may be controlled by spraying, at least twice, with arsenate of lead—2½ lbs. of paste to 40 gallons of water.

The first application should be made as soon as the flies begin to emerge, that is, *about June 25th* in the warmer portions of the province, such as the Niagara-Burlington districts and the counties bordering Lakes Erie and St. Clair and the Detroit River; *about July 1st* in moderately warm sections, such as most of the remaining counties west of Toronto and those along Lake Ontario as far east as Lennox and Addington; *about July 7th* in the counties farther north and east. In a cold, backward season this application should be put on one week later than the dates specified.

The second application should be given as soon as the first shows signs of disappearing, usually this will be about three weeks later. It must be borne in mind that the flies continue to emerge for about seven weeks, and that it is therefore essential to have poison on the trees for that length of time. In wet weather this may mean one or more extra applications.

Every application should be fairly heavy, and all trees in and around the orchard, except those with fruit nearly ripe, should be sprayed.

All useless seedling apple trees and hawthorns should be cut down.

THE APPLE MAGGOT.

(*Rhagoletis pomonella Walsh.*)

From time to time the Apple Maggot or, as many fruit-growers call it, the Railroad Worm, has appeared in large numbers in various parts of Ontario. In some orchards it has destroyed the entire crop and in others a large percentage of it. Such attacks have caused great anxiety not only to those whose orchards were infested, but also to all the fruit-growers who heard of the damage the insect had done, and who feared that it might spread to their orchards. Their fears were increased by learning that there was no known practicable remedy for the insect in large commercial orchards, the old remedy of gathering and destroying the fruit being considered impracticable except in small orchards.

In 1909 and 1910 the Apple Maggot was abundant in a number of localities east of Toronto. In the latter year the senior author visited these localities, saw the extent of the injury, learned of the fears of the fruit-growers, not only in the immediate vicinity but also many miles away, and then brought the matter to the attention of the Provincial Fruit Branch in Toronto. The result was that he was authorized to begin a study of the insect with the object of finding, if possible, a satisfactory method of control.

The first year of the investigation the junior author acted as an assistant, but after that year became a full partner in the investigation, in which henceforth he represented the Dominion Entomological Branch, to which he had been appointed at the end of the first year's work. Hence since 1911 the study of the insect and its control has been carried on as a joint enterprise of the Dominion and Provincial Departments of Agriculture.

Most of the life-history work was done during the years 1912 and 1913, after which time it was abruptly ended by the almost total disappearance through natural factors of the insects in the orchard in which the investigation was being carried on. However, every year since then observations and some further study have been made in various orchards. Infested orchards have also been found each year on which control measures have been tested.

Fig. 2.—Apple Maggot adults on fruit, natural size.

Fig. 3.—Wing of Apple Maggot adult, enlarged about twelve times.

The main object in view in beginning the investigation—the finding of a satisfactory method of control—has been attained. The additional object, to work out the life-history of the insect, has been largely accomplished, though there are several points, some of them of much importance, on which definite knowledge is still lacking. It is hoped that as soon as a favorable opportunity presents itself these points may be cleared up.

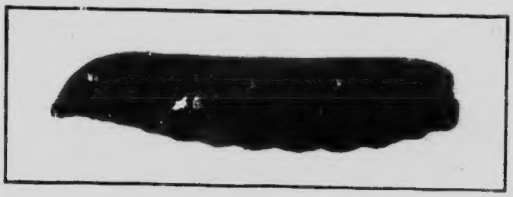

Fig. 4.—Larva of Apple Maggot, much enlarged, lateral view.

Description of the Insect.

The Apple Maggot is the larva or maggot of a pretty two-winged fly, a little smaller than the house-fly. The general color of the fly is black, but the eyes,

Fig. 5.—**Pupa of Apple Maggot, much enlarged.**

when the light shines on them, are a beautiful golden green, and the head and lower part of the legs are yellow. The abdomen of the female is crossed by four broad white bands and that of the male by three. Near the middle of the back there is a small, distinct, white, somewhat triangular area, and a white stripe runs along each side of the thorax from the base of the wings to the head. The wings have conspicuous dark brown markings or bands arranged as shown in Fig. 3. The arrangement of these markings makes it easy to distinguish this species from closely allied species like the two Cherry Fruit-flies.

The larva when full grown is a small, legless, nearly cylindrical, white maggot, about one-quarter of an inch long. One end of the body is blunt and the other pointed. There is no visible head, but at the smaller end there are two little black hooks which are used to rasp and tear the pulp of the fruit and free the juices,

Fig. 6.—**Section through an infested apple, showing a full grown larva, natural size.**

which are then absorbed through a small opening close to the hooks. (See Figs. 4 and 6.) The larvæ are very small and hard to find in the apple until it is ripe. Then they grow quickly, and when the apples are mellow or over-ripe they can be found with ease in the broken down and decaying tissues.

How to Recognize the Work of the Apple Maggot.

To determine whether an apple is infested by the Apple Maggot cut it through with a knife and observe whether there are little, brown, irregular areas and streaks here and there throughout the flesh, as shown in Fig. 7. If they are

Fig. 7.—Cross-section of apples showing the work of the Apple Maggot before the apples are ripe.

present the probability is that the apple is infested, the brown areas or streaks being due to the killing of the tissues by the maggots as they work in various directions. There is a possibility, however, that the browning may be due to the disease known as Bitter Pit, Stippen or Internal Dry Rot. This common disease may show on the surface of the fruit as small pits or sunken areas, usually about one-eighth of an inch in diameter. Often, however, there is little or no evidence of the disease on the surface, but when the fruit is cut open many brown, dead areas will be found in the flesh. These are arranged usually in a much more regular manner than the brown areas caused by the Apple Maggot, and are as a rule more uniform in shape and size, being frequently about one-tenth of an inch in diameter and nearly circular. Sometimes, however, they vary much in size and shape. (See Figs. 8 and 9.)

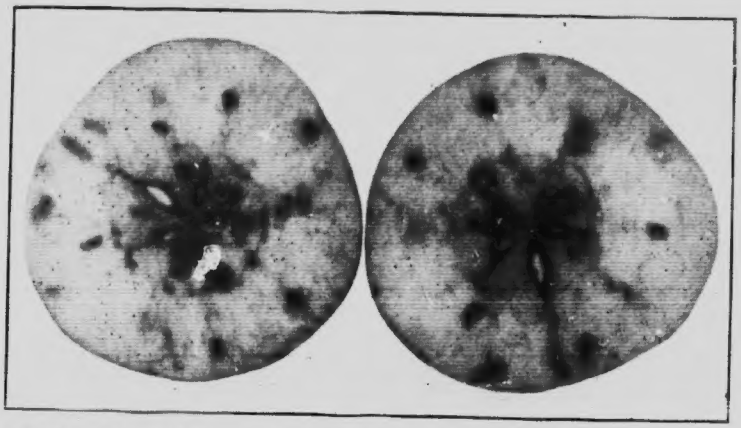

Fig. 8.—Cross-section of apple showing dead areas due to the Bitter Pit disease.

A simple method of determining definitely whether the browning of the inner tissues is due to the Apple Maggot or to the Bitter Pit or Dry Rot disease is to examine the surface of the fruit for evidences of the egg punctures made by the adults of the Apple Maggot. If these are present it is clear evidence that the apple is infested by the insect; if they are not present the trouble is due to Bitter Pit

Fig. 9.—Cross-section of apples showing a different form from Fig. 8 of injury due to Bitter Pit disease.

Fig. 10.—Apple showing egg-punctures of the Apple Maggot in apples, natural size.

or Internal Dry Rot. Egg punctures are almost always easily seen even with the naked eye. (See Figs. 10 and 11.) They show as small, brownish, circular spots, about the diameter of an ordinary pin, and are usually, though not always, situated in little depressions caused by the tissues injured by the ovipositor not

growing while those around them continue to grow. Sometimes a little white waxy substance forms over the puncture and conceals the brown colour.

The presence, therefore, of egg punctures and browned dry tissues within the fruit is clear proof of Apple Maggot infestation.

Fig. 11.—Apples showing egg-punctures and accompanying depressions, slightly reduced in size.

Brief History.

The Apple Maggot is by no means a new pest either in Canada or the United States. There are records of its presence in the United States more than fifty years ago, and in Ontario for more than thirty years. There seems to be no doubt that it existed in both Canada and the United States long before these dates, in fact the evidence strongly indicates that it is a native North American insect, and that before apples were introduced it probably bred in haws, later on acquiring the habit of attacking apples. Though present for so long a time it was not described or given its scientific name until the year 1867, when this was done in the United States by Walsh. In Ontario the late Dominion Entomologist, Dr. James Fletcher, reared it from haws in 1887, and since 1896 it has been reported from time to time in the province as an enemy of the apple. In the provinces of Quebec, New Brunswick and Nova Scotia the insect has doubtless attacked apples for many years, but definite records of its work do not go back in Quebec more than about twenty years, and in the other two not even that long.

Further information on the history of the insect in North America may be obtained from Bulletin 171, Agricultural Experiment Station, Durham, New Hampshire.

Present Distribution in the Province.

When this investigation was begun, it was supposed that the Apple Maggot occurred only in a few localities in three or four counties of the province, and was, therefore, a very local pest. The writers, however, largely as a result of their own observations have found it to be present in the following counties:—Carleton, Dundas, Grenville, Leeds, Lennox and Addington, Hastings, Prince Edward, Northumberland, Durham, Ontario, York, Peel, Wentworth, Lincoln, Welland, Norfolk, Kent, Essex, Lambton, Middlesex, Brant, and Wellington. These counties extend from the Ottawa River on the east to Lake Huron and the Detroit River on the west. The other counties have not to any appreciable extent been inspected, but it is reasonable to assume that since the insect has been found in so many counties it probably occurs in every county where apples are grown. Its range is, therefore, wide. Fortunately, the total number of orchards infested is small, probably less than 5 p.c. in any county, and much less than 1 p.c. in the province as a

whole. In fact, in several counties the insect was found only in apples growing in towns and villages, places where the conditions seem to be specially favorable for its existence.

Food Plants.

In Ontario the Apple Maggot has been found infesting only the fruit of apples, crab apples, and a few of the many species of haws. In parts of the United States* a fruit fly seemingly identical with it except in being smaller has been bred from huckleberries and blueberries. In British Columbia† a similar insect is common in the fruit of snowberry. However, as neither of these insects, according to present knowledge, will breed in apple, there is some doubt as to whether they are really the same species as the Apple Maggot. This doubt is strengthened by the fact that the adults of the blueberry-huckleberry form and of the snowberry insect are very timid and difficult to capture even with a net, whereas the adults of the apple species are sluggish and may be readily captured with a cyanide bottle without the aid of a net.

Comparative Degree of Susceptibility to Attack of the Different Varieties of Apples and Crabs.

Any person who examines a moderately-infested orchard will readily discover that some varieties of apples are much worse attacked by the Apple Maggot than others. This is so commonly true that those who are familiar with the insect's habits, when seeking to discover whether it is present in any particular orchard, always ask to be shown certain varieties such as Early Harvest, Sweet Bough, Gravenstein, Snow, Wealthy, Alexander, Tolman or Spy, because they know that these are among the insect's favorites, and that if it is in the orchard at all it will be found on some of these.

In seasons when there is not a great number of flies these or other favorite varieties may be the only ones attacked, or the only ones at all severely attacked, but in seasons when the flies are very abundant almost every variety will have many apples infested, while not a single fruit may escape on the favorite varieties. The only varieties that have been exempt from attack in the orchards under observation were the Arctic and Stone, but as these were found only in moderately-infested orchards it is no proof that in the case of a badly-infested orchard they would escape.

It is worth mentioning that in the early part of the season the insects usually confine their attention to their favourite earlier varieties; then as the season advances and these become nearly ripe, they attack the later ones. For instance, a Snow apple and an unnamed early fall apple were situated side by side. At first the fruit on the Snow was uninfested, whereas the flies were readily observed ovipositing on the fruit of the other tree and numerous egg punctures could be seen. A week or two later the flies became common on the Snow fruit and it became just as badly punctured as the other, almost every apple being attacked. Tolman Sweet is a variety very subject to attack, yet many eggs will be laid in early varieties before oviposition begins on it.

The following table gives the result of the writers' observations upon the degree to which the different varieties of apples and crabs are subject to attack. It does not include all varieties grown in Ontario, but only those found in the orchards studied.

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*Woods, W. C.—Maine Agr. Exp. Sta. Bul. 244, pp. 252-266.
†Downes, W.—Can. Ent., Vol. LI, No. 1, pp. 2-4, Jan., 1919

TABLE I.—SHOWING THE DEGREE OF SUSCEPTIBILITY TO ATTACK OF THE VARIOUS VARIETIES OF APPLES AND CRABS.

Alexander—Moderately susceptible.
Astrachan.—Slightly susceptible.
Arctic—Very slightly, if at all, susceptible.
Baldwin—Slightly susceptible.
Baxter—Slightly susceptible.
Ben Davis—Moderately susceptible.
Blenheim—Slightly susceptible.
Brockville—Slightly susceptible.
Cayuga—Moderately susceptible.
Colvert—Moderately susceptible.
Cooper's Market—Moderately susceptible.
Cranberry Pippin—Moderately susceptible.
Duchess—Slightly susceptible.
Early Harvest—Very susceptible; one of the worst attacked.
Gideon—Moderately susceptible.
Golden Russet—Slightly susceptible.
Haas—Moderately susceptible.
Holland Pippin—Slightly susceptible.
Hurlburt—Slightly susceptible.
Hyslop Crab—Moderately susceptible.
Jennetting—Moderately susceptible.
King—Slightly susceptible.
Maiden's Blush—Moderately susceptible.
Mann—Very slightly susceptible.
McIntosh—Slightly to moderately susceptible.
Pewaukee—Slightly susceptible.
Phœnix—Moderately susceptible.
R.I. Greening—Moderately susceptible.
September Sweet—Very susceptible; one of the worst.
Snow—Very susceptible; one of the worst.
Spy—Very susceptible.
Stark—Slightly susceptible.
St. Lawrence—Moderately susceptible.
Stone—Apparently immune.
Strawberry Seedling—Very susceptible; one of the worst.
Sweet Bough—Very susceptible.
Tolman—Very susceptible; one of the worst.
Transcendent Crab—Very susceptible.
Wagner—Moderately susceptible.
Wealthy—Very susceptible; one of the worst.
Whitney Crab—Moderately susceptible.
Wolf River—Very slightly susceptible
Yellow Bellflower—Moderately susceptible.
Yellow Transparent—Slightly susceptible.

Exceptions.

In most districts natural fruit or seedling trees are to be found and where these occur in an infested orchard they almost without exception are severely attacked.

Some of the varieties classed above as only slightly or moderately susceptible are sometimes under exceptional circumstances, such as the absence of other more susceptible varieties, severely attacked. For instance, Duchess is usually but little infested, yet at Lyn, Leeds County, a crop of Duchess was in 1915 almost totally ruined by the Apple Maggot. In this case the explanation seemed to be that the flies had almost no option but to attack this variety.

Nature of the Injury and Economic Importance of the Insect.

A brief account of the nature of the injury done by this pest has already been given under the heading "How to Recognize the Work of the Apple Maggot," but fuller details are desirable.

The female fly lays her eggs in the fruit after first piercing the skin with her sharp sting-like ovipositor. (See Fig. 12.) The egg is placed in the pulp a little below the surface. After hatching the larvæ begin to work their way here and there through the flesh, tearing the tissues with their hooks as they go and absorbing the juice thus liberated. The injured tissues die and turn brown, thus

Fig. 12.—Abdomen of female showing the ovipositor protruded (much enlarged).

leaving a trail wherever the larvæ go. There may be as many as forty or fifty eggs laid in a single apple, hence many brown trails may be found crossing and re-crossing each other. Thus a large proportion of the cells of the apple may be drained of their juices and become brown and tough in texture. Such apples are often spoken of as "woody" and are not fit for sale or even for home use. They are likewise not good for canning or evaporating.

So long as the apple is firm and not ripe the maggots remain small and the interior of the apple does not collapse, but from the time the fruit begins to ripen

Fig. 13.—Cross-section of over-ripe apple showing the way the maggots often break down the tissues.

until it is over-ripe the maggots grow rapidly, probably because of the plentiful supply of sugar now available. They then soon destroy so much of the pulp that large collapsed areas here and there may be seen in it when cut open; in fact, in some cases almost the whole interior may become a broken down, unsightly, rotting mass. (See Fig. 13.) Most apples would of course be marketed before this state

Fig. 14.—"Knobby" apples, malformations due to the work of the Apple Maggot.

of affairs had ensued; nevertheless the process would continue in the marketed fruit, and the purchaser would be disappointed and disgusted when he came to use the apples.

As to the effect upon the exterior of the apple, most varieties that have many egg punctures soon become noticeably deformed as a result of the numerous sunken areas, brought about partly by each egg puncture checking growth wherever it occurred and partly by the maggots at times working near the surface, killing the tissues below the skin and preventing the proper, uniform development of the fruit at such places. These badly-deformed apples are sometimes spoken of as "knobby." (See Fig. 14.)

A third injury is caused by the tendency of many infested varieties of apples to drop prematurely. This is a common occurrence and has been noted especially in the case of Alexander, Wealthy, Snow, Spy and Cayuga.

Fig. 15.—Apple showing the tunnels of larvæ close to the skin.

Inasmuch as whole orchards may have almost every apple badly infested and ruined, it is clear that the Apple Maggot is capable of causing great losses, and were it commonly distributed in all orchards of the province as the Codling Moth is it would rank as the worst of apple insects. Fortunately, as has already been shown it is not found in most orchards in any county, and in fact very seldom in as many as 5 per cent. of the orchards of any one county. In many counties it seems to be restricted almost entirely to villages and towns, often, however, doing much damage in these. In no one orchard is it equally abundant every year; some years it almost disappears, but a few years later becomes numerous again.

In concluding this aspect of the subject, it may be said that if for any reason the orchards in any part of the province where the insect is now at all common were to become neglected or left unsprayed, there is good reason to believe that the insect would gradually spread through these and in years favourable for its development destroy great quantities of fruit.

LIFE-HISTORY.

The Apple Maggot like other two-winged flies goes through four stages in its life-history, namely, the adult or fly, the egg, the larva or maggot and the pupa. These will each be discussed now in turn.

The Adult.

Time of Earliest Emergence.—The time at which the first flies appear in the orchard depends chiefly upon climate, though moisture may play some part. In the warmer parts of Ontario the flies begin to appear earlier than in the colder parts, and in any particular locality they appear earlier in a warm season, especially if June has been warm, than in a cold season.

In cages at Bowmanville in 1911 the first fly emerged on July 10th, in 1912 on July 6th and in 1913 on July 7th. In 1913, however, flies had emerged at Bowmanville in a village orchard earlier than July 6th, for several egg punctures were found on July 9th and several of the eggs laid had hatched. Therefore, allowing five days at least from emergence to oviposition and five days for the eggs to hatch, emergence must have taken place as early as June 30th and probably a few days earlier.

In 1914 daily inspections of an orchard in Dundas County were made and the first two flies were seen emerging from beneath a heap of decayed apples on July 10th, though no flies were observed on the trees till July 14th. At Vineland, Niagara district, in the same year they began emerging on July 2nd.

In 1915 the first flies were seen at Simcoe in Norfolk County on July 6th. Daily observations had also been made in the orchard here before this date.

In 1916 in Leeds County, on July 18th, ten flies were found and about thirty egg punctures. These flies must have emerged by July 8th, and probably a few days earlier.

In 1917 in Leeds County, in this same locality the date of emergence must have been later than in 1916, because no flies could be found on July 14th or 15th, though they appeared later. The date was not determined because the writers could not remain longer in the district.

In 1918 at Belleville four flies, but no egg punctures, were found on July 10th, and at Brighton the first fly was seen on July 13th. Careful daily searches had been made in the orchard at the latter place for a week or more before this date.

The above data would lead to the belief that in an average year the flies begin to emerge about the first week in July. We believe, however, from the fact that at Bowmanville in 1913 several flies had evidently emerged the last week in June, and that in 1914 they began emerging eight days earlier in the Niagara district than in Dundas County, we are justified in assuming that in the warmer parts of the Province such as the counties in the Niagara district and along Lake Erie, emergence regularly begins in a warm season about June 25th, along the north shore of Lake Ontario about July 1st, and further east and north about July 7th. In a cold season these respective dates would each be about a week later. In any season we should expect the flies to emerge a little earlier in a sunny, sheltered orchard than in an exposed one. It is interesting to learn that in Nova Scotia with its more backward spring the flies do not begin to emerge until about a month later than in Ontario.

TABLE 2. SHOWING DATES OF EMERGENCE OF APPLE MAGGOT ADULTS AT BOWMANVILLE, 1912.

Daily Emergence.		Daily Emergence.	
Date	Number	Date	Number
July 6	1	August 1	14
" 7	3	" 2	14
" 8	8	" 3	10
" 9	11	" 4	9
" 10	33	" 5	14
" 11	53	" 6	12
" 12	55	" 7	5
" 13	37	" 8	5
" 14	53	" 9	5
" 15	22	" 10	1
" 16	26	" 11	3
" 17	26	" 12	2
" 18	30	" 13	9
" 19	24	" 14	1
" 20	32	" 15	1
" 21	36	" 16	0
" 22	21	" 17	2
" 23	34	18	0
" 24	16	19	3
" 25	16	20	2
" 26	44		
" 27	44		
" 28	30		
" 29	23		
" 30	32		
" 31	17		
		Total	830

SUMMARY OF TABLE 2.

1st week, July 6—July 12, 164 adults or 19.7%
2nd week, July 13—July 19, 218 adults or 26.2%
3rd week, July 20—July 26, 199 adults or 23.9%
4th week, July 27—Aug. 2, 174 adults or 20.9%
5th week, Aug. 3—Aug. 9, 60 adults or 7.2%
6th week, Aug. 10—Aug. 16, 8 adults or .96%
7th week, Aug. 17—Aug. 20, 7 adults or .84%

TABLE 3.—SHOWING DATES OF EMERGENCE OF APPLE MAGGOT ADULTS AT BOWMANVILLE, 1913.

Daily Emergence.		Daily Emergence.	
Date	Number	Date	Number
July 7	1	August 1	8
" 8	0	" 2	21
" 9	0	" 3	2
" 10	2	" 4	8
" 11	0	" 5	8
" 12	0	" 6	3
" 13	0	" 7	5
" 14	2	" 8	3
" 15	0	" 9	0
" 16	4	" 10	0
" 17	4	" 11	4
" 18	8	" 12	4
" 19	5	" 13	1
" 20	7	" 14	0
" 21	17	" 15	5
" 22	13	" 16	4
" 23	6	" 17	1
" 24	19	" 18	1
" 25	16	" 19	1
" 26	34	" 20	0
" 27	14	" 21	0
" 28	18	" 22	4
" 29	16	" 23	1
" 30	18	" 24	0
" 31	21	" 25	0
		" 26	0
		" 27	1
		" 28	0
		" 29	1
			Total 311

SUMMARY OF TABLE 3.

1st week, July 7—July 13,	3 adults or	.96%
2nd week, July 14—July 20,	30 adults or	9.6%
3rd week, July 21—July 27,	119 adults or	38.2%
4th week, July 28—Aug. 3,	104 adults or	33.4%
5th week, Aug. 4—Aug. 10,	27 adults or	8.6%
6th week, Aug. 11—Aug. 17,	19 adults or	6.1%
7th week, Aug. 18—Aug. 24,	7 adults or	2.2%
8th week, Aug. 25—Aug. 29,	2 adults or	.64%

Emergence for the first few days as seen in the tables and observed in the various orchards is slow, especially if the weather is cool, but it soon accelerates and in a week or so numerous flies may be seen on the trees if the year is to be one of bad infestation.

Time of Maximum Emergence.

An examination of Tables 2 and 3 shows that the vast majority of the flies emerged during the last three weeks in July. Observations in the orchards indicate that the flies are present in greatest numbers the latter part of July and the first two weeks in August.

Time of the Disappearance of the Flies from the Orchard.

The tables show that adults may continue to emerge up to almost the end of August; however, the percentage of those emerging after the first week in August is small and by the 20th of that month the number of individuals to be found on the trees diminishes quickly. By the end of August they have often totally disappeared. Some years, however, they continue to be found in small numbers up to the middle of September.

The following data have been obtained on the date of disappearance. In 1911 at Bowmanville all had gone by August 27th, and in 1915 at Simcoe by August 31st.

In 1912 a few flies were found at Bowmanville up to September 15th and in 1917 at Stoney Creek (Niagara district) up to September 17th. Accurate data have not been obtained for the other years.

Length of Life of the Flies.

In cages well protected from excessive heat, three individuals (one male and two females) were kept alive for over five weeks, and a single female for forty-six days, or six weeks and four days. The great majority, however, of the many flies used in the experiments died much earlier. Some writers suppose that because flies do not act normally in cages they therefore live longer in the open and that under normal conditions in the orchard they probably live for at least five weeks. This is very doubtful, because, as shown in tables 2 and 3, large numbers of flies emerge the last week of July, and yet in the orchard it is not unusual to find all the flies gone by August 31st. It would therefore seem justifiable from the tables and the information given above on the date of disappearance to suppose that the average length of life was not much more than three weeks, though some individuals may live a good deal longer. It is likely that some years many flies die in times of drought from lack of moisture just as they do in cages. It is also likely that chilly nights towards the end of August kill many.

Proportion of Males to Females.

In rearing cages the number of males compared with females was as follows:—

	Males.	Females.
In 1912	292	538
In 1913	85	226
In 1914	44	76
Totals	421	840

This shows that almost twice as many females as males emerged from the cages. Yet in the orchard on almost every occasion each year the males appeared to be more numerous than the females, the proportion often being as high as four males to one female. The explanation of these conflicting facts has not been found.

Habits of the Adults.

In an infested orchard the flies may readily be observed on the leaves and fruit. They are sluggish, much more so than most species of flies. This characteristic is more pronounced during cool weather and in the early morning. In the warm part of the day they are as a rule most in evidence and most active, and as might be expected usually prefer the sunny side of the tree. Here, when not feeding, the majority may, especially in hot weather, be found resting on the under surface of the leaves. This is also a common place of refuge during rain.

The feeding habits of the flies have given the clue to the only satisfactory method of control; hence a knowledge of the structure of the mouth parts and of the feeding habits is important. The mouth parts resemble those of the common house-fly. Fig. 16 shows their general appearance when protruded as in search of food. When not feeding they are usually withdrawn into a fold in the head where they are more or less concealed. At the outer extremity there is, as shown

Fig. 16.—Head of Apple Maggot adult, showing mouth parts protruded, greatly enlarged. Observe the large lip-like structure and the row of rasps on its surface.

in the figure, a broad structure which when closely examined resembles a pair of lips, and can be opened or closed like lips. On the lower or feeding surface of these lips, are numerous rasping structures which are used with the assistance of a salivary secretion to help in breaking down and dissolving solid substances; for solids cannot be fed upon until they are either dissolved or broken up into such minute particles that they can be sucked in along with the liquid.

Feeding commences soon after emergence and continues as long as flies are present in the orchard. Freshly emerged adults placed in vials invariably applied their mouth parts to the sides and lapped up the moisture adhering to the glass. On the trees individuals when not resting may be observed numerous times in the day moving about over the leaves and fruit with their mouth parts applied to the surface in search of food. We have observed them feeding upon water, aphis honey-dew, apple juice, sweetened and non-sweetened liquid poisons, also upon dry arsenate of lead, whether sweetened or not. Our observations indicate that they will attempt to feed upon almost any substance, whether liquid or solid, which they find upon

the surface of the foliage or fruit and that there is no evidence that they are attracted to any particular substance or bait.

Length of Time From Emergence Until Eggs are Laid, or Preoviposition Period.

When the flies emerge the eggs in their ovaries, as shown by dissections, are in a very immature stage and a number of days are required to elapse before egg-laying can begin. How long this period is has not been definitely determined nor has any satisfactory method of discovering it been found. Large numbers of newly emerged flies were confined in various kinds of cages but only three individuals laid eggs. In two of these instances the preoviposition period was thirteen and fourteen days respectively and in the third twenty-four days. Several females were observed making futile attempts to oviposit when they were from eleven to sixteen days old.

The foregoing data would indicate that probably eleven days was the minimum period, but it would not be safe to consider that this was correct, because flies do not act normally in cages. O'Kane in New Hampshire and Bi[illegible]in in Nova Scotia found that in a few cases, but only in a very few, flies in cages oviposited in less than a week. Our observations in the orchard would lead us to believe that in the case of some individuals at least the period may not be longer than a week and possibly shorter.

Egg-laying Habits.

The female fly has a sharp, sting-like ovipositor, as shown in Fig. 12. When ready to oviposit she raises herself on her legs, bends the abdomen at almost a right angle and gradually by repeated thrusts forces the ovipositor through the skin of the apple into the pulp beneath. The egg is then passed down and deposited a short distance below the skin. The whole operation takes from thirty seconds to seven minutes with an average of about one and a half minutes. Once the ovipositor has been withdrawn it is carefully cleaned or brushed by the hind legs.

A fly has been observed to deposit several eggs in half an hour, but the total number of eggs laid by any one fly during her life has not been determined. An examination of the ovaries shows that each female is potentially capable of laying several hundred eggs.

Many eggs may be laid in a single apple. In one case ninety-three egg punctures were found in a Snow, and in six Snow apples on the same tree a total of three hundred and ninety-three egg punctures.

Flies sometimes go through all the actions of ovipositing without any eggs being laid. The total percentage of such eggless punctures is not easy to determine accurately, but is apparently small.

The Egg.

Description.—The eggs are very small, white or cream in colour, nearly elliptical in shape and almost four times as long as wide. Being situated in the pulp beneath the skin they can be seen only by dissecting them out.

Length of Incubation Period.

The length of [illegible]od was determined for fifteen eggs. Seven of these required five days ea[illegible], hatch; four, six days; two, seven days; one eight and one nine. The larger number therefore hatched in five days, but the average was six days. These determinations were made during the month of August in 1912.

Mortality of Eggs.

By the examination of a large number of egg punctures it was found that eggs had hatched in an average of 78.7 per cent. of these. The remaining 21.3 per cent. represent eggs that for any reason, such as infertility, failed to hatch and also punctures made without any eggs being laid. As the percentage of the latter was difficult to determine accurately no attempt was made to separate the two.

TABLE 4.—SHOWING THE PERCENTAGE OF EGG PUNCTURES IN WHICH THE EGGS HATCHED AND THE PERCENTAGE MORTALITY.

Variety	No. of Egg Punctures	No. of Eggs Hatched	Percentage Hatched	Percentage Mortality
September Sweet.....	947	778	82.2	17.8
Snow	690	420	63.7	36.3
Spy.....	503	439	87.3	12.7
Seedling	237	209	88.2	11.8
Total	2347	1846	Average 78.7	Average 21.3

The Larva.

Description.—The larva is maggot-like and when full grown about a quarter of an inch long, white in colour, roughly speaking cylindrical, blunt at one end, and tapering towards the other. It has no legs and no distinct head. Two little black hooks at the small end act as jaws and tear the tissues of the pulp, thus releasing the juice, which is then absorbed through the inconspicuous mouth. Though legless the larva can move about slowly, both inside the fruit and on the soil after emerging.

Larvæ are hard to see in the fruit until it is very ripe, because they remain small so long as the fruit is immature, but develop rapidly after it has ripened.

Length of Larval Life.

The length of larval life varies greatly because it depends entirely upon the fruit itself; since the larvæ never mature no matter how long they are in the apples until these are ripe, or more correctly mellow and often beginning to break down. Hence in harvest apples the larval life may be not more than about three weeks, whereas in winter apples such as Spy it may be more than two months.

Mortality of Eggs and Larvæ Combined.

We have already pointed out that not all of the eggs which are laid hatch: nor do all the larvæ hatched from the eggs reach maturity. The total percentage of mortality in both stages is high, and in the case of infested winter varieties may be as high as 100 per cent. The data presented in Table No. 5 indicates that the early varieties of apples lend themselves particularly well to the breeding and multiplication of this insect and that in winter varieties only a small number of maggots survive.

TABLE 5.—SHOWING THE PERCENTAGE OF MORTALITY OF EGGS AND LARVAE COMBINED IN 1912 AND 1913.

Variety	Date Apple Dropped	No. of Apples	No. of Punctures	No. of Larvae Emerged	Percentage Mortality
1912					
Harvest	Aug. 15	32	242	52	78.5
Early Seedling	" 15	15	300	26	91.4
September Sweet	Sept. 7	17	960	114	88.1
Spy	" 13	23	147	2	98.6
Snow	" 13	24	190	6	96.8
Spy	Oct. 5	many	many	0	100
Tolman	Sept. 18	26	many	0	100
Tolman		many	many	0	100
1913					
Harvest	Aug. 11	99	192	70	63.5
Early Seedling	" 22	64	175	83	52.5
Tolman	Sept. 13	54	208	3	98.5
Snow	Aug. 25	78	344	172	50.0
Snow	Sept. 11	87	478	92	80.8

Number of Larvæ per Apple.

The greatest number of larvæ obtained from a single badly infested fruit was 12. From twenty-two apples of the September Sweet variety 207 larvæ were

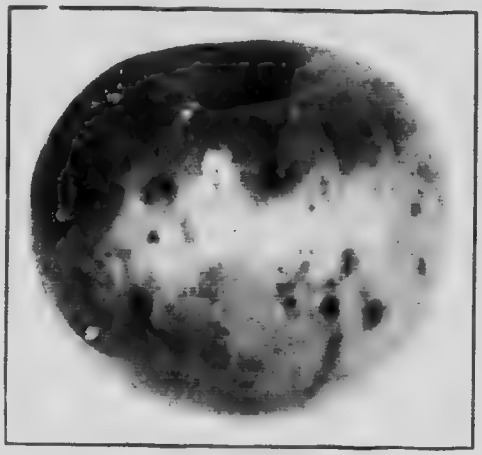

Fig. 17.—Apple showing many egg-punctures and three exit holes, the latter being each several times larger than any of the former.

reared, or an average of 9.4 per apple. It is seldom, however, that the number reaches nearly so high as this, and in winter varieties, as shown above, it is very small.

Emergence of Larvæ from the Fruit.

When the larvæ are full grown they make a hole in the skin of the fruit and work their way out through it. (See Fig. 17.) By this time the fruit has almost always fallen. Occasionally a few apples hang on the trees and rot, and any larvæ in them simply come out and drop to the ground. Once out of the apples the larvæ seek a suitable place to pupate.

The Pupa.

The larva or maggot of many species of two-winged flies when full grown and ready to pupate contracts the larval skin into an oblong or barrel-shaped case called a puparium and later within this case changes to a true pupa. Fruit growers, however, never see this real pupa and always speak of the puparium as the pupa. For the sake of simplicity it seems advisable to follow this custom and to use the term pupa to include both the puparium and the real pupa within it.

The larvæ of the Apple Maggot usually pupates within twenty-four hours after leaving the fruit. The pupa in size and shape resembles a small plump grain of wheat. At first it is golden-brown in colour but becomes darker with age. (See Fig. 5.)

Where the Pupæ are Found.

A few pupæ may be found within rotting fruit, especially crab apples; a large number occurs just below rotting apples, especially if these are in a heap; but the vast majority are within the soil itself and at an average depth of between one and two inches. A considerable number are sometimes in the third inch, but very few out of the hundreds examined in various soils were deeper than this. In grass or sod they are not, as a rule, found quite so deep as in cultivated, loose soil. If the soil is hard they may often be found on the surface hidden around the crown of the grass or other plants.

Duration of the Pupal Stage.

All the pupæ remain in the various situations mentioned here, unless destroyed in some way, until the following summer. Then by far the greater number of them transform and emerge as flies. The remainder stay in the soil as pupæ all that season and the following winter, and the second summer at the usual time emerge as adults, thus making a two year life cycle for these instead of the more common one year life cycle.

Data on the Two Year Life Cycle.

From pupæ of the year 1911, in 1913 there emerged 5 females and 4 males, and from 61 pupæ of 1912 in 1914, 3 females and 1 male.

In the fall of 1913 the following percentages of healthy pupæ were recovered from four rearing boxes: 12 per cent., 10 per cent., 18 per cent. and 10 per cent. respectively. These, therefore, belonged to the two year cycle.

From a rearing box in which an unknown number of maggots pupated in 1913, 64 flies emerged in 1914 and 19 in 1915, that is 23 per cent. of the total number of flies secured from this cage had the biennial habit.

Is There a Second Brood of Adults?

All the evidence obtained at Bowmanville from our life-history studies, in which this point was kept in mind, showed that in that locality, and doubtless in similar or colder localities, there is not a second brood. At Grimsby, however —a much warmer part of the province—an adult male and several apparently fresh egg punctures were found on September 25th, 1915, though all adults in the equally warm district of Simcoe, Norfolk County, had disappeared by August 31st. This caused a suspicion that there might be a partial second brood at Grimsby. To test this, in 1917 badly-infested Early Harvest apples were placed under cheesecloth beneath a large peach tree where they were sheltered from

the sun. The tree was 100 feet or more away from the nearest apple tree. Between September 19th and 21st two adults emerged in this cage. These were all that emerged. This indicates that there is a partial second brood some years in the south-western or warmer parts of the province. It must, however, be a very small and almost insignificant one, otherwise the flies could scarcely have escaped our attention.

Do Flies From Pupæ From Early Varieties Emerge Earlier Than Those From Later Varieties?

Large numbers of infested summer, fall and winter (Tolman) varieties were collected in 1911 and placed in ground boxes. The next spring 300 pupæ from the summer and 300 from the fall apples were put in the ground cages. Unfortunately, no pupæ were obtained from the winter apples, doubtless because of the failure of the maggots to mature. On July 8th flies commenced to emerge from the pupæ derived from fall apples and on the following day from those from the summer apples. The exact data are as follows:

Summer Varieties:

Cage 13, flies commenced to emerge July 9th.
Cage 16, " " " " 10th.
Cage 17, " " " " 10th.

Fall Varieties:

Cage 14, flies commenced to emerge July 8th.
Cage 15, " " " " 10th.
Cage 18, " " " " 10th.

This shows that so far as summer and fall varieties go there is no difference between the dates of emergence. It is very doubtful whether any difference would be found even if pupæ from winter varieties had been used, and it is probably safe to consider that the earliest flies seen in the orchard on any particular tree may not have come from the infested fruit of that particular tree alone but also from that of the other infested trees whether early or late varieties.

Natural Control.

It has been shown that there is commonly a great mortality of eggs and larvæ in the fruit, often reaching in the case of winter varieties to as high as 100 p.c. and even in the case of summer varieties seldom going below 50 p.c. The causes of this mortality are not known except that in winter varieties it is apparently due to the fruit not becoming sufficiently mellow to allow the larvæ to mature, enter the soil and pupate before the very cold weather comes and destroys them.

Not only do great numbers of eggs and larvæ perish, but also numerous pupæ; in fact, it would appear that the greatest mortality often occurs between the time when the larvæ leave the fruit and the time for emergence of adults the following summer. Some years the destruction of pupæ is much greater than others. For example, we have several times placed numerous badly infested very ripe apples in heaps so that the following year we might secure flies from the pupæ from these if desired. Some years many flies could thus be secured, other years almost none. Similarly in boxes the number of flies emerging from a known number of pupæ of the previous year varies greatly from year to year. For instance, in 1912 53 p.c. of the pupæ in boxes transformed to flies, whereas in 1913 only 26.9 p.c.

The much g[illegible]er mortality of the insects some years than others leads, of

course, to there being much less injury some years than others. Every student of the Apple Maggot must have observed this great fluctuation in numbers. The insect will become very abundant in an orchard for a year or commonly for several years, then almost disappear for several years, only to reappear in large numbers later. Our knowledge of the factors responsible for these great fluctuations is very meagre. Parasitism by other insects is apparently of little if any importance, because in none of our experiments with eggs, larvæ, pupæ and adults did we secure any parasites, nor did we see any evidence of their work in the orchard. It is true that a four-winged parasite has been found in Nova Scotia, but even there only in small numbers. Birds doubtless feed upon exposed larvæ and pupæ, spiders upon adults, ants upon larvæ when seeking to pupate and upon flies when emerging and still helpless, and there is reason to suppose that ground beetles sometimes destroy pupæ. But the combined work of these enemies is not sufficient to account for the extraordinary decrease in numbers of the Apple Maggot some years compared with others. The main cause is probably due to the difference in weather conditions of one year compared with another, but just how weather conditions act is not very clear. The following appear to be possible explanations:—

First, if there have been heavy rains in June followed by drought the surface of the soil becomes hard and baked and many flies will be unable to emerge through it; for instance, in 1912 only 40 flies emerged from 200 pupæ in a box where the soil was heavily watered and then packed to form a firm surface, while in a check box where this was not done 106 emerged out of 200.

Second, if the soil is very hard and baked many larvæ after leaving the fruit are unable to enter it and many others do so only with great difficulty. In October, 1913, 95 newly emerged larvæ were placed in orchard soil which had been beaten by rain and baked by the sun. Only 42 of these were able to enter the soil, the others pupating on the surface.

Third, a hard condition of the surface soil, as just stated, leads to many larvæ pupating above ground either on the exposed surface or among the roots of grass and weeds. Such pupæ in a time of drought usually perish. In a box 100 pupæ were exposed on the loose surface of the soil and from these only one fly emerged. In the same way it is reasonable to suppose that since many pupæ in almost any soil are found in the first inch of soil and since pupæ cannot withstand prolonged absence of moisture very many of these must perish in years when the soil becomes dried out for long periods in July and early August.

From what has been said above it would follow that the insects would ordinarily be most numerous in situations where the soil is of such a nature as to allow the larvæ to find good pupation quarters with ease, or in other words orchards in which the soil surface is loose either from late cultivation year after year or because the trees are thick, affording a dense shade, and where weeds and rubbish abound on the ground. The fact is that usually it is just such orchards, provided they have not been regularly and heavily sprayed with a poison each year, that are worst infested. Fruit trees in villages and towns are commonly worse infested year after year than those in orchards, and apparently chiefly for the reason that conditions in the former are specially favourable for pupation. Such trees are usually situated in gardens that are on the one hand kept well cultivated, or on the other hand abound in weeds and rubbish to such an extent as to prevent the baking of the soil. Moreover, in towns and villages strong, drying winds cannot play the same part that they do in a more exposed orchard.

CONTROL MEASURES.

Cultural Methods.

Experiments with pupæ in plots in which the soil was frequently stirred showed that such stirring had practically no effect in lessening the number of adults that emerged. Moreover, some of the worst infested orchards were those on which good cultivation was practised. As the pupæ lie loose in the earth, one would not expect them to be injured by stirring. The fact would appear to be that cultivation, especially if continued late, would favour the increase of the insects, because it would afford more nearly ideal conditions for pupation.

Deep ploughing may bury many of the pupæ under five or six inches of earth, but this does not prevent the flies from coming up. We found that when pupæ were buried even eighteen inches deep flies still emerged: other experimenters have had the same experience. So that neither as a result of stirring the pupæ or burying them deeply is cultivation any assistance as a control measure.

Soil Insecticides.

When the work was begun, and before a satisfactory method of control was discovered, it was hoped that an insecticide might be found which by being worked into the soil would destroy the pupæ. The following substances were tested at even greater strengths than would have been practicable under orchard conditions: Apterite, Vaporite, Cliff's Manurial Insecticide, Vermine, Jeye's Fluid, brine, lime-sulphur, pyrethrum in water, kerosene emulsion, bluestone and lime. Some of these reduced the number of emerging adults considerably, but as these substances are all expensive and, as a much cheaper and much more satisfactory remedy has been found, it is unnecessary to consider them further.

Chickens.

Wherever many chickens have free run of the orchard and the latter is cultivated, large numbers of the pupæ are devoured and sometimes the pest is held completely in check.

Destruction of Fallen Fruit by Hand or by Domestic Animals.

There is no doubt that if all the fallen fruit is gathered sufficiently frequently and destroyed, and this continued over a period of two years, it will practically eliminate the Apple Maggot, unless infested orchards are close by. This was demonstrated in 1911, 1912 and 1913 in a small isolated orchard near Bowmanville. Hogs were utilized to some extent in the work, but most of it was done by hand.

This method is applicable rather to a few trees in a village or town garden than to a commercial orchard. The amount of work involved even on one acre when the crop was heavy was found to be vastly greater than anticipated, and so great that almost no fruit-grower would perform it: in fact it is in our opinion an impracticable method of control in commercial orchards, except possibly in the few cases where hogs, sheep or cattle are allowed to run in the orchard in sufficiently large numbers to keep the ground free from "drops."

Much data was obtained on the frequency with which drops of the different varieties should be gathered to prevent larvæ emerging, but an account of this under the circumstances seems unnecessary.

Spraying With Arsenicals.

A study of the structure of the mouth parts and of the feeding habits of the adults have led investigators of this insect to believe that if poisons were sprayed on the leaves and fruit these would be fed upon and cause death.

At first it was supposed that the poison must be in the form of a liquid and that it must be combined with some sweet, attractive substance, such as molasses, before the flies could or would feed upon it. Later, however, both as the result of cage experiments and of orchard observations and tests, it was seen that the poison need not be in liquid form, but that arsenate of lead could be used. The next discovery was that the molasses or any other sweetened substance was not necessary, because the flies fed upon the small particles of arsenate of lead even after all the water used in the spraying had evaporated. The fact that molasses may be omitted and that the arsenate of lead and water are sufficient is a great boon, because molasses is costly, tends to injure the foliage, and causes the mixture to wash off faster than it otherwise would.

Experiments on Control by Spraying With Arsenicals.

That spraying with arsenicals will control the Apple Maggot even in the worst infested orchard has been proved by us as the result of six years' spraying experiments. At first, as will be shown, the results were inconclusive, because of defects in the methods employed, but with experience these weak points were eliminated and the last three years' tests gave most gratifying results. Cage experiments with poisoned sprays were also conducted, and not only corroborated the orchard results, but also demonstrated that the flies would feed upon the poison even where they had an opportunity of not doing so. These cage experiments will be referred to after the orchard experiments have been described.

Experiment 1. In 1913 at Bowmanville the Early Harvest and September Sweet trees in a village orchard were sprayed just as the flies began to emerge, and again four times later at intervals of a week or more, the large number of applications being due to the excessively wet weather in July and August. The mixture used was 2 lbs. arsenate of lead to 40 gals. of water containing 1 gal. of molasses. The remainder of the trees, including one Snow apple, were left unsprayed as a check. The results were inconclusive, for though there were fewer infested apples on the sprayed trees than on the Snow, yet a large number of the sprayed apples had also been attacked.

Experiment 2. In 1914 a large orchard of 25 acres or more at Mountain, in Dundas County, was sprayed twice with 2 to 3 lbs. arsenate of lead and 1 gal. of molasses to 40 gals. of water. The first spray was applied just as the flies began emerging, and the second between two and three weeks later. Suspecting that the failure to secure satisfactory results the year before was due to our having sprayed too small a portion of the orchard, it was decided that all the main bearing part should be treated, leaving as a check a block of about two acres arranged in four rows along the east side. This orchard had been badly attacked the previous year and many of the infested apples left upon the ground to rot. It contained many varieties, including several which were favourites of the Apple Maggot.

The result of the experiment as seen in September was that in the whole orchard, including the check, after much searching only ten apples with Apple Maggot egg punctures were found. This, of course, looked like a remarkable

example of natural control and not the result of spraying; but there is no doubt that if it had not been for the spraying a considerable percentage of at least the favourite varieties like Tolman, Snow and Wealthy would have been infested; because at the close of the first application in July and again during the second application in August several dozen flies were observed on the trees, and there is no question that flies were also present in the interval between the two applications, though probably not in large numbers. Where flies are present eggs are sure to be laid unless the flies are killed by poison. Natural enemies do not destroy them to a sufficient extent to bring about the above result.

As to the freedom of the check from injury by the pest, there are two possible simple explanations. First, the season was very dry and the Codling Moth application, which had been heavy that year, still remained on the foliage to a considerable extent at the time of the first spraying for the Apple Maggot; hence the flies may have been destroyed by this poison. Second, the check strip was only 8 or 10 rods wide, and the flies as they moved about may have passed, and almost without doubt did pass, from the unsprayed to the sprayed trees and *vice versa*, thus becoming poisoned before they were ready to oviposit.

In an unsprayed orchard half a mile away approximately 50 p.c. of the fruit on the most susceptible varieties was punctured.

Experiment 3. In 1915 a small orchard of about 30 large trees at Villa Nova, in Norfolk County, was sprayed twice with the same mixture as used in 1914. As the season was very wet more applications should have been given, but, from lack of time, had to be omitted. Even so, the results were very c[illegible] for, out of a small crop of only a few barrels, not more than from 10 p.c. [illegible] p.c. had been attacked. The orchard was completely isolated and had been severely infested the previous year.

Experiment 4. In the same year an orchard in the suburbs of Simcoe was sprayed seven times with sweetened arsenate of lead. This large number of applications was necessary on account of frequent rains to keep the foliage and fruit covered with the poison. The results obtained here were disappointing, for though the spraying must have reduced the percentage of infested fruit, yet nearly 75 p.c. of the Tolmans and from 10 p.c. to 40 p.c. of the Snow and Spy apples were punctured. The cause of the failure of these numerous applications to protect this orchard was evidently the same as in the case of the Early Harvest and September Sweet trees in the Bowmanville orchard in 1913, namely, the proximity of other infested trees or small orchards to the sprayed trees. At Simcoe there were several such orchards a few rods away from the treated one. It is possible, too, that some of the very heavy wind storms may have had something to do with bringing in fresh flies, for in the worst storms the wind blew from the untreated orchards towards the treated. Up to the time of the first, which was also the worst, of these storms, no egg punctures and very few flies had been found, but after this there was a noticeable increase of the flies, and egg punctures soon followed. This, of course, is not proof that the wind was responsible for bringing in the flies, though if the facts could be known it would probably be found to be the correct explanation of their increased number.

Experiment 5. In 1916 three small orchards situated near each other at Lyn, in the County of Leeds, were each sprayed twice with the sweetened poison. The season was dry and the spray remained on well. These orchards had been so badly infested the previous year that most of the fruit had been left unpicked. Two of the orchards were on one side of the road and the other on the opposite side. No

other orchards were to the south, east, or west of these, but to the north were several similar small ones, the nearest being 15 rods or so away. These orchards had also been badly attacked the previous year and were now left unsprayed as a check. Between these checks and the two sprayed orchards mentioned as being situated on the one side of the road, were a hedge and building which served to isolate them fairly well. The other sprayed orchard on the opposite side was not so well isolated, having no barrier between it and the checks. The result of the spraying was that the two orchards most isolated had over 96 p.c. of the apples on all varieties, including such susceptible ones as Tolman, Snow and Wealthy, free from egg punctures. The orchard on the other side of the road was not quite so clean, some of the Tolmans having as high as 25 p.c. of the apples punctured, though most of these had only one or two punctures each. In the check orchards on both sides of the road the Tolman, Wealthy, Snow and St. Lawrence had from 75 p.c. to 99 p.c. of the fruit with egg punctures, most of the apples having each many punctures.

Experiment 6. In 1917 these same three orchards were resprayed, this time with 2 to 3 lbs. arsenate of lead to 40 gals. of water without the addition of any molasses. As the season was very wet in July three applications instead of two were given to all except the summer varieties such as Duchess and Yellow Transparent. In addition, all trees in the nearest part of the check block were sprayed once in order to afford the test orchards some protection. The results were excellent: for in the most isolated orchard the fruit was all free from injury, and in the second best isolated orchard only a dozen apples on a Baxter tree had been punctured. (These egg punctures could all have been made in a single day by one female.) The third orchard in which some of the Tolmans in the previous year had as many as 25 p.c. of punctured fruit was almost as clean as the other two, not more than three score apples being affected, and these having each only one or two punctures. The check trees were not so badly infested as the previous year, though Snows, Wealthy, and St. Lawrence, and a seedling variety, had almost every apple attacked. (The Tolmans in the checks had no crop this year.)

Experiment 7. At Trenton this same year, 1917, an old isolated orchard of about thirty trees which had been badly infested in 1916 was heavily sprayed twice with arsenate of lead and water. Here, too, the result was that the fruit was almost entirely free from injury, only one dozen apples being found with any egg punctures. There was no check for this orchard.

Experiment 8. In the autumn of 1917 the worst infested orchard the writers had seen was found near Brighton. There were approximately 300 trees in it. The varieties were chiefly Ben Davis and Wealthy, with several Snow, one Yellow Bellflower, two or three Golden Russets, one St. Lawrence, one Tolman and a few other varieties. There had been a moderate crop that year, but every apple seen had been so badly attacked by the Apple Maggot as to be worthless and most of them had been left on the ground to rot. This would naturally give an ideal opportunity for a great number of flies to be present the next year, and thus for a thorough and final test of the poison spray. Accordingly arrangements were made whereby the entire spraying, including that for Apple Scab and Codling Moth, was taken in charge. Five sprays in all were given, namely, the dormant or semi-dormant spray, the spray just before the blossoms opened, the one just after the blossoms fell and then two more for the Apple Maggot itself. The first of these Apple Maggot applications was on July 12th and 13th, just as the first flies began to appear and the second the first week in August.

In order to protect the orchard from reinfestation from surrounding orchards the first orchard to the east was well sprayed, and also the one to the west, the owner himself doing the latter. This left only one unsprayed orchard nearby. It was situated over a height of land about 10 rods north of the extreme north-east corner of the sprayed orchard. This orchard, because of the elevation of the land between it and the test orchard and because of the direction of the prevailing winds, was felt not to be a menace and so was used as a check. The mixture used in the spraying was 2 to 3 lbs. arsenate of lead paste to 40 gallons of water.

The result of the spraying was very gratifying, for the orchard was not only beautifully free from Scab and Codling Moth, but also had less than 3% of the fruit infested by the Apple Maggot. This estimate includes fallen apples as well as those on the trees. One tree had between 5 p.c. and 8 p.c. of infested fruit, but this was far the worst tree, most of the trees having less than 1 p.c. and several being entirely free from injury. On the Tolman, which is usually as badly attacked as any variety, only two punctured apples could be found. There is no doubt that these results were due entirely to spraying, for one of the writers visited the orchard every two or three days from the time the flies began to emerge up to the end of July, and found that numerous flies were present. Some days fifty or more could be seen on any one of many trees, thus proving that if it had not been for the spraying there would have been plenty of flies to have utterly ruined the crop It was observed, too, that the poison must have had an effect upon the flies very soon after emerging, because of the several hundred flies seen on various occasions none were found mating nor was there any evidence of egg laying up to the date mentioned.

In the check orchard, which, according to the owner, had not been badly infested the previous year, and from which most of the fruit had been sold that year, not nearly so many flies per tree, even on the most susceptible varieties, could be found; in fact, 8 or 10 flies were all one could usually find in an hour. Some of these flies were mating and egg punctures could readily be found before the end of July. By the close of the season there were so many infested apples in it that the chief apple buyer of the county refused to purchase the fruit at any price. The same buyer, after carefully inspecting the sprayed orchard, not only stated that, in his opinion, the fruit was in first-class marketable condition, but also purchased the crop. In the check orchard we made a careful examination of Snow, Wealthy, Ben Davis and Phoenix trees and estimated that all of these had 75 p.c. and upward of the apples infested, many of the apples having so many egg punctures as to be deformed.

Cage Experiments on the Effect of Arsenical Poisons upon the Apple Maggot.

A series of experiments extending for one month was carried on in cages to see how long it took arsenate of lead and calcium arsenate respectively to kill the flies, and to test the effect of adding molasses to the former substance. A few tests were also carried on with a substance used in dusting orchards, composed of finely ground sulphur 85 p.c. and arsenate of lead powder 15 p.c.

The cages used were the ordinary Riley cages with cheesecloth on three sides and glass in front. In each of the check cages an apple branch with a few apples on it was placed in a bottle of water to keep it alive and healthy. This branch was, of course, taken from an unsprayed tree, and no poison put on it. In the cages where poison was used two small branches or twigs from this same tree were

placed in bottles of water and the foliage and fruit of one of these was dipped in the poison mixture, while that on the other was not poisoned, the object being to see whether the flies in feeding would avoid the poisoned twig in favour of the other and thus escape death.

All cages were placed in an open air insectary built under the shelter of a large apple tree on the side of a steep hill, so that they were sheltered from the sun's rays and had the benefit of a constant movement of air.

TABLE 6.—SHOWING THE EFFECT OF ARSENICAL POISONS UPON THE ADULTS IN CAGE EXPERIMENTS.

Substance used.	No. of tests made	Total No. of flies used	Percentage of flies dead in 1 day	Percentage of flies dead in 2 days	Percentage of flies dead in 3 days	Percentage of flies dead in 4 days	Percentage of flies dead in 5 days
Arsenate of lead	5	46	17.4	56.5	78.2	94.6	100
Arsenate of lead and molasses	10	113	21.9	60.5	85.9	97.3	100
Calcium arsenate (arsenate of lime).	10	89	56.2	85.4	98.9	100	.....
Sulphur 85% and arsenate of lead powder 15% dusted on fruit and foliage ..	4	37	24.3	51.6	81.1	81.1	91.5
Checks	9	97	0	1.0	5.1	6.2	6.2

An examination of the above table shows clearly the killing effect of the poison, the checks representing the normal death rate. It shows too that the flies in all the poisoned cages fed upon the poisoned foliage and fruit as well as upon the unpoisoned, and therefore have little or no power of selection, or at least, are not repelled by the poison. Calcium arsenate killed more rapidly than arsenate of lead, but unfortunately is not safe to use alone with water, as it will burn the foliage severely. Sweetened arsenate of lead killed a little, but only a little, more quickly than arsenate of lead alone. Arsenate of lead powder combined with sulphur was the slowest killing substance, some of the flies in these cages not dying until the sixth day. All poisons killed more than 50 p.c. of the flies in two days, and the vast majority in four days. The fact that a fly does not die for four or five days does not mean that it is as healthy as ever during most of this period: in fact, the poison seems to have an effect almost from the first in preventing mating and egg-laying.

The great advantage of using arsenate of lead and water without any molasses is its safety to the foliage and fruit, and its excellent sticking qualities which necessitate fewer applications.

DIRECTIONS FOR CONTROL.

The above experiments in orchards and in cages have shown that spraying with arsenate of lead is a satisfactory method of controlling the Apple Maggot. Similar results to ours have been obtained by Brittain and Good in Nova Scotia.

To make the spraying a success it must be done at the right time and every tree in the orchard must be sprayed; moreover, if there are badly infested orchards or trees close by they also must be sprayed. Failure to do this is evidently the explanation of the lack of success obtained by some investigators. It is a dangerous assumption to make that the flies do not move around from tree to tree in the orchard. The results obtained by spraying show that both this insect and its close relatives, the Cherry Fruit-flies, do move about much more than was previously supposed.

The mixture recommended is arsenate of lead paste 2½ lbs. to 40 gals. of water without any molasses or other sweetening. Arsenate of lead powder would perhaps do as well, but there is some doubt whether it sticks quite so long on the foliage.

The *first application should be given as soon as the flies begin to emerge* so that they may be killed before they can lay eggs. Hence the *date of this application* in an ordinary season in the warmer portions of the Province, such as all the counties bordering on Lakes Erie and St. Clair and the Detroit River, together with the Niagara and Burlington districts, *would be about June 25th;* in the moderately warm counties, such as the most of the remaining counties west of Toronto and those along Lake Ontario as far east as to Lennox and Addington it would be *about July 1st;* and in the counties farther north and east *about July 7th.* In a cold, backward season, especially if June is cold, this application should be postponed in each of these districts about one week.

The *second application should be made as soon as the first shows signs of disappearing.* Usually this will be in about three weeks, but in two weeks if the weather is wet. *A third application in about another two weeks should be given if there have been many heavy rains to wash off the second and is a good insurance in all cases the first year after a bad infestation.* It is necessary to remember that flies continue to emerge in the orchard for about seven weeks, and that the poison must be on the trees all that time to control them.

Every application should be fairly heavy, almost as heavy as for the Codling Moth: because the heavier and more thorough the application is the longer the poison will remain on the fruit and foliage.

At the first application no tree, whether bearing or not, should be left unsprayed, for the flies may remain on the foliage of a tree that has no fruit until they are ready to lay eggs and then for this purpose seek a tree with fruit. It is also well for the same reason to spray plum, cherry and pear or other trees if many of these are present.

At the second and third applications only those trees whose fruit is nearly ripe and that if sprayed would be dangerous to the consumer, should be omitted.

If infested orchards are close by, every effort should be made to have the owners co-operate by spraying them: for otherwise some years it will be found difficult to secure a high percentage of clean fruit. If, however, the orchards are 20 rods or so away the danger from them is not usually great.

All useless seedling apple trees and all hawthorns should be cut down or sprayed, as the insect will breed on them too.

In towns and villages where there are usually only a few apple trees in each garden, it is not easy to control the insect; because spraying the trees of one garden and not those of the neighboring gardens is not sufficient. In such cases keeping the fallen fruit picked up and shaking off and gathering all infested fruit just before it becomes ripe and then boiling or burning this, where there are no hogs or cattle to which it may be fed, will help much if widely practised. The best plan, however, would probably be to purchase a community spray machine and pay somebody to spray all the trees in the village according to the directions given above. Every kind of fruit tree should be sprayed and not apples alone. A line of hose 100 feet or more in length would make the work easier as it would avoid the necessity in many cases of driving the machine into the gardens. If such a machine were purchased it could be used also for all the regular sprays that are so valuable in producing clean fruit.

Two years of careful treatment should almost exterminate the Apple Maggot in any orchard unless situated close to untreated, infested orchards. One year's treatment is not sufficient because some of the pupae, as previously shown, pass two winters instead of one in the soil. The flies from these would therefore attack the apples the second year no matter how complete the control of the pest the first year.

After two years' treatment it should be possible usually to rely upon the regular Codling Moth spray or this supplemented by one application the first week in July.

There seems no doubt that wherever the Codling Moth spray has been heavily applied year after year it has controlled the Apple Maggot, but where it was applied lightly or applied some years and omitted others it has not done so.

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The use of a poison spray to control the Apple Maggot was first suggested to the writers by the results obtained from sweetened poisons on other species of fruit-flies in Italy and South Africa. The main suggestions, however, were received from the work of J. F. Illingworth, of Cornell University, Ithaca, N.Y., who was the first entomologist in North America to demonstrate the value of this method against Cherry Fruit-flies and the Apple Maggot.